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Die Dool in the Insulation of Automotive Primary Wiring

■ INTRODUCTION

Die dool occurs in an extrusion process when the material being extruded adheres to the face of the die and builds up over time. Die dool occurs in many types of extrusion processes but is a particular problem in processes employing the continuous vulcanization (CV) technique, such as the insulation of automotive primary wiring. In the CV technique, the die is enclosed by a tube filled with high pressure steam and is inaccessible during continuous vulcanization. This inaccessibility prevents the removal of the accumulating material by the operator of the line.

Eventually, the dool releases from the die in one of two ways:

1. The dool can attach to the wire insulation in the form of a complete or partial ring of material, commonly referred to as a die ring, horse-collar, donut, or fuzball. These rings create problems in the automated harnessing operation by causing wire breaks or acting as faults in the insulation.
2. Die dool that does not adhere to the insulation falls into the CV tube and is washed down the tube by steam condensate. If the die dool is only partially crosslinked when it detaches from the die face, numerous particles can adhere to one another, forming larger pieces. These larger pieces sometimes clog steam traps, screens and water seals and result in unscheduled shutdowns. These large pieces of die dool can also adhere to the wire during shutdowns, sometimes causing line breaks when the line is restarted.

■ CAUSES OF DIE DROOL

Die dool appears to emerge from the die as a secondary flow, separate from the primary flow of the extrudate. The cause of this secondary flow is not well understood, but it is clearly influenced by all of the process variables that affect the flow of material through the extruder. These variables include the compound, the extruder and tooling design, and processing conditions. It is very rare, however, that the adjustment of a single variable completely eliminates die dool.

Although unfilled polyolefins produce die dool under certain circumstances, highly filled compounds generally produce die buildup at a substantially higher rate and at much lower temperatures than the corresponding unfilled polymers. The level of filler in the compound appears to strongly influence the rate at which the compound generates die dool, probably due to interactions between the filler and polymer. Whether these filler-polymer interactions are physical or chemical in nature is not known.

The base resin of the compound being extruded also influences the rate at which the compound generates die dool. Even similar polymers produced on different types of reactors (for example, resins produced on tubular reactors versus those produced on autoclaves) sometimes generate die dool at different rates. This variability may be due to different levels of low molecular weight species in polymers produced on different reactors. Low molecular weight species have long been suspected of contributing to die dool as these oligomers can volatilize upon exiting the extruder.

Moisture in the compound has been known to aggravate the generation of die dool. Some extrusion systems seem to be more sensitive to the level of moisture in the material than others, emphasizing the fact more than one factor is usually involved in the generation of die dool. As produced, wire and cable compounds have a very low level of moisture, but the moisture content can increase with high humidity conditions or from rain water in leaking trucks, warehouses or silos.

■ MINIMIZING DIE DROOL

A key factor in minimizing the generation of die dool is control of the melt temperature of the compound during processing. For this reason, adjustments that lower and stabilize the melt temperature generally reduce the generation of die dool. Correctly sizing extrusion equipment is the first step, as a more uniform melt temperature is achieved when the majority of the heat input is frictional (shear) heat. Undersized extruders may need to operate at extremely high screw speeds generating excessive melt temperatures, while oversized extruders may require substantially more electrical heat which can lead to localized hot spots and aggravate die dool. Similar problems can occur with short L/D extruders, 15:1, for example.

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Drool in the Insulation of Automotive Primary Wiring *(continued)*

Mixing screws, such as barrier screws, screws with Maddock elements and pin screws, are not generally recommended for automotive primary wire insulation. Mixing screws can be used only if specifically tailored to maintain lower melt temperatures when extruding highly filled compounds.

Individual temperature controllers should not override the set point nor fluctuate by more than 5°F. Screw cooling can also be effective in controlling melt temperature. Tempered die cooling reduces overheating of the die due to contact with the steam and may be the single most effective process variable for reducing the generation of die drool. Bear in mind even sophisticated water cooling systems can become ineffective when cooling lines are blocked or when water temperature is poorly controlled. Such systems need to be monitored and maintained to perform as desired.

Any obstructions or imperfections at the die exit collect material. Once the buildup of material at the die exit is initiated, the buildup generally continues to occur. For this reason, the condition of the die face is very important in reducing die drool. Dies should be frequently cleaned and checked for damage and wear. Care should be exercised to avoid damage to dies during changing. Dies in poor condition should be replaced.

In general, certain die designs help reduce the generation of die drool. Undersized dies, approximately 97% of wire diameter, typically result in less die drool than onsize or oversized dies. It is also recommended that single-angle dies with very short lands (less than 0.015") be used.

Finally, cooling of the die is extremely effective in reducing die drool. The effect on die drool of certain other design variables, such as entry angle, relationship of die angle to guider angle and gum spacing, is not yet fully understood.

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